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PROGRESS REPORT 235-5

QUARTERLY REPORT

CAVITATION DAMAGE IN  
LIQUID METALS

Report of Progress  
for the Period

2 April 1963 - 2 July 1963

By

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**CAVITATION DAMAGE IN LIQUID METALS**

**Report of Progress for the Period**

**2 April 1963 - 2 July 1963**

**SUMMARY:**

During the current period maximum effort was applied to design a new research test facility for cavitation damage testing of refractory materials in liquid sodium at high temperature. A feasibility study has been completed which will incorporate a sodium loop into a vacuum dry box. The new dry box will include an integral elevating mechanism to house the magnetostriction device and allow in place calibration. Detailed purchase specifications are in preparation and invitations to bid will be circulated to qualified manufacturers in the early part of the next report period.

A systematic series of experiments were performed to determine how small variations of geometric parameters associated with the magnetostriction apparatus would affect cavitation damage rate with a view toward standardizing test conditions for all future experiments. The results indicate that beaker size, liquid depth and depth of immersion have no effect on cavitation damage rate within the limits tested. Specimen size appears to affect the damage rate considerably and therefore a fixed size is necessary. This size is based primarily on convenience of specimen preparation and ease of examination.

It has been established that a rimmed specimen is not required to achieve reproducibility of damage in the steady zone. A flat faced specimen is more desirable since it has equal reproducibility to the rimmed type, is not subject to

localized rim damage, and is more convenient and less expensive to machine and make visual observations.

A work schedule for the next period is included at the end of the report.

EXPERIMENTS TO STANDARDIZE THE TEST PARAMETERS OF MAGNETOSTRICTION APPARATUS:

The essential test parameters of the magnetostriction apparatus are shown in Figure 1. The nomenclature is as follows:

- a - amplitude of vibration of the specimen
- f - frequency of oscillation
- r - radius of the specimen
- d - depth of immersion of the specimen
- H - depth of test liquid in the beaker
- D - diameter of the beaker
- $\lambda$  - wave length of sound in the liquid

So far there has never been any systematic analysis of the effect of the above parameters on the rate of cavitation damage except a few isolated experiments without any specific conclusions. Before undertaking any detailed investigations on the resistance of materials by making use of this apparatus, it is necessary to know the effect of small variations in the above parameters so that proper care will be taken to control them as required. With this objective in view the following experiments were carried out under the present program of research. Tap water and aluminum specimens were used in these experiments as a matter of speed and convenience.

Effect of Specimen Shape It is the general practice to use a circular test specimen with a flat test face (shown in Figure 2(b) for Cavitation damage tests. However, Plesset (1) reported that it was difficult to get reproducible results with

this flat faced specimen and introduced the "dished" specimen idea (as shown in Figure 2(a) with the claim that this type of specimen would give a better reproducibility of the results. During the present experiments with liquid sodium it was found that the rim damage (the rim of the specimen would break off in the middle of an experiment due to the damage produced by a ring of bubbles entrapped in the tip vortices) was a serious difficulty with this type of experiment. Furthermore, the machining and control of the test surface finish are much more difficult than the flat faced specimens. These considerations lead to a reexamination of the effect of specimen shape with particular reference to the necessity of the rim. Figure 3 shows the relationship between the damage rate and the testing time for four identical flat faced specimens at a given amplitude and frequency. Figure 4 shows the same relationship for three identical Plesset, dished specimens. The amplitude in this case had to be lower because of rim damage at higher amplitudes. One can easily see that the reproducibility of results with a flat faced specimen is in no way inferior to the specimens with rim. Figure 5 shows the rate of damage as a function of amplitude for both types in the steady zone and there seems to be no difference provided there is no rim damage. It has been decided to adopt a simple flat faced specimen as a result of these investigations.

Effect of Depth of Test Liquid in The Beaker: It has been suggested earlier that the depth of liquid in the beaker had an effect on the damage rate because of the wave reflections in the liquid (2). It has been further recommended that this depth should be a half wave length of sound in that liquid for the test frequency so that a standing wave is produced. Figure

6 shows the relationship between the rate of damage and the relative depth of liquid (water) with respect to the wave length at 15 kc/s. There seems to be little effect on damage rate due to the wave reflections up to about  $2 \frac{1}{2}$  wave lengths. It has been observed that the damage rate decreases if the depth is decreased below 0.3 wave length. Hence the depth of liquid in the beaker will be kept more than a half wave length.

Effect of the Diameter of the Beaker: There seems to be little effect of the diameter of the beaker on the rate of damage as shown in Figure 7. (Showing the relationship between the rate of damage and the relative diameter with respect to the wave length of sound in the test liquid).

Effect of Depth of Immersion of Specimen: Rheingans (3) found that the depth of immersion of the test specimen had an effect on the cumulative damage; furthermore, this effect depended upon the test duration. Because of the two interacting variables, he failed to come to a definite conclusion regarding the magnitude of the effect of the depth of immersion on damage. Present experiments on this aspect conducted in the steady zone (thereby eliminating the time effects) show that the rate of damage in the steady zone is independent of the depth of immersion of the test specimen up to one radius of the specimen as shown in Figure 8.

Standardization of Test Parameters: As a result of this analysis, the following criteria for standardization of the test parameters in the magnetostriction apparatus have been formulated. The beaker dimensions do not seem to have any specific effect on the rate of damage and hence a reasonably practical size may be selected. The rate of damage is independent of the depth of immersion of the specimen up to one radius of the specimen. A flat faced specimen may be selected for testing

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because of its simplicity. Experiments on the effect of variation of specimen diameter on damage rate is in progress and will be reported during the next period.

### PLANS FOR THE NEXT REPORT PERIOD

1. Purchase new refractory dry box and all associated components and instrumentation.
2. Perform accelerated cavitation damage tests of pure iron, nickel 201 and titanium 100A in liquid sodium up to 1000°F. and compare with available water data.
3. Determine effect of amplitude and temperature on the cavitation damage rate of 2.
4. Perform experiments to correlate the change in damage rate as a function of specimen diameter.

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1. Plesset, M.S., On Cathodic Protection in Cavitation Damage, Trans. A.S.M.E., Journal Basic Engineering, Dec. 1960, p. 809.
2. Robinson, L.E., B.A. Holmes and W. C. Leith, Progress Report on Standardization of The Vibratory-Cavitation Test, Trans. A.S.M.E., Vol. 80, 1958, pp. 103-107.
3. Rheingans, W.J., Accelerated-Cavitation Research, Trans. A.S.M.E., Vol. 72, 1950, p. 709.

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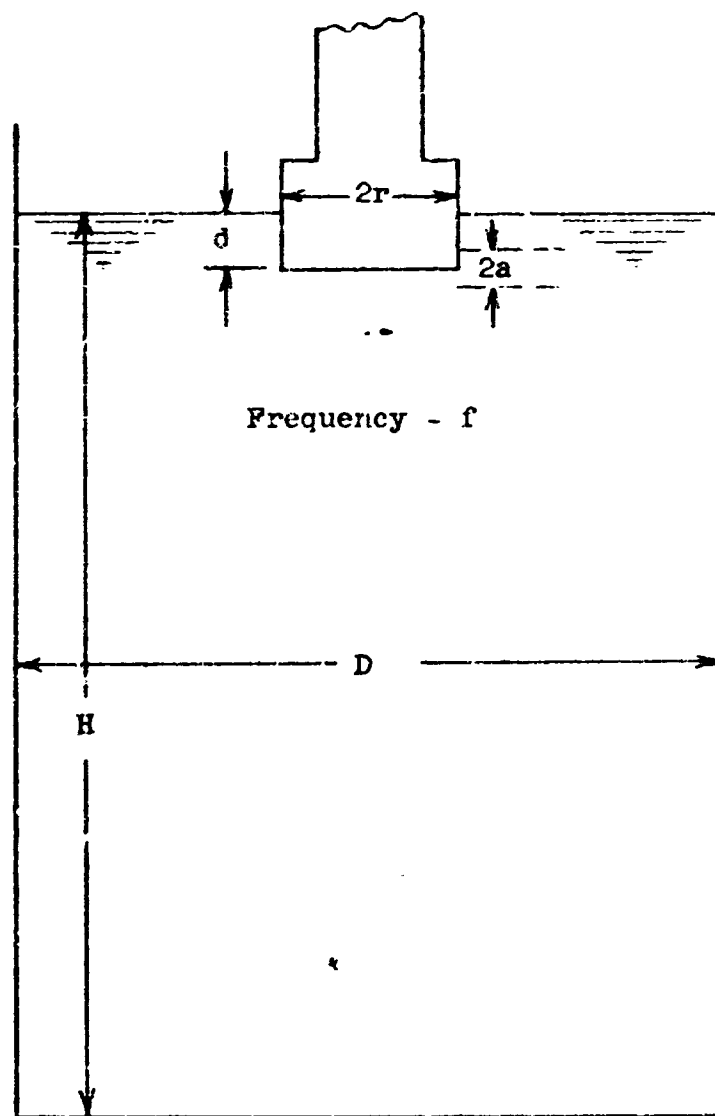
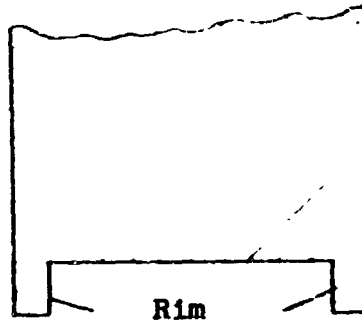
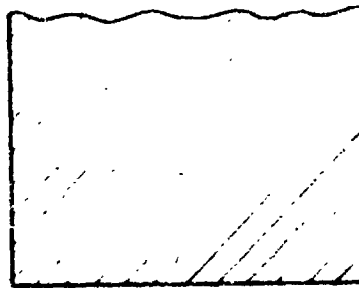


FIGURE 1. DEFINITION SKETCH OF THE MAGNETOSTRICTION APPARATUS

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**a) Plesset's Rimmed Specimen**



**b) Flat Specimen**

**FIGURE 2. TWO TYPES OF SPECIMENS TESTED FOR REPRODUCIBILITY**

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Material: 1100-0-Aluminum  
 Liquid: Water @ 80°F.  
 Amplitude:  $1.55 \times 10^{-3}$  inch.  
 Frequency: 15 kc/s:

Specimen No.

- |   |   |   |
|---|---|---|
| ○ | - | 1 |
| □ | - | 2 |
| ◇ | - | 3 |
| △ | - | 4 |

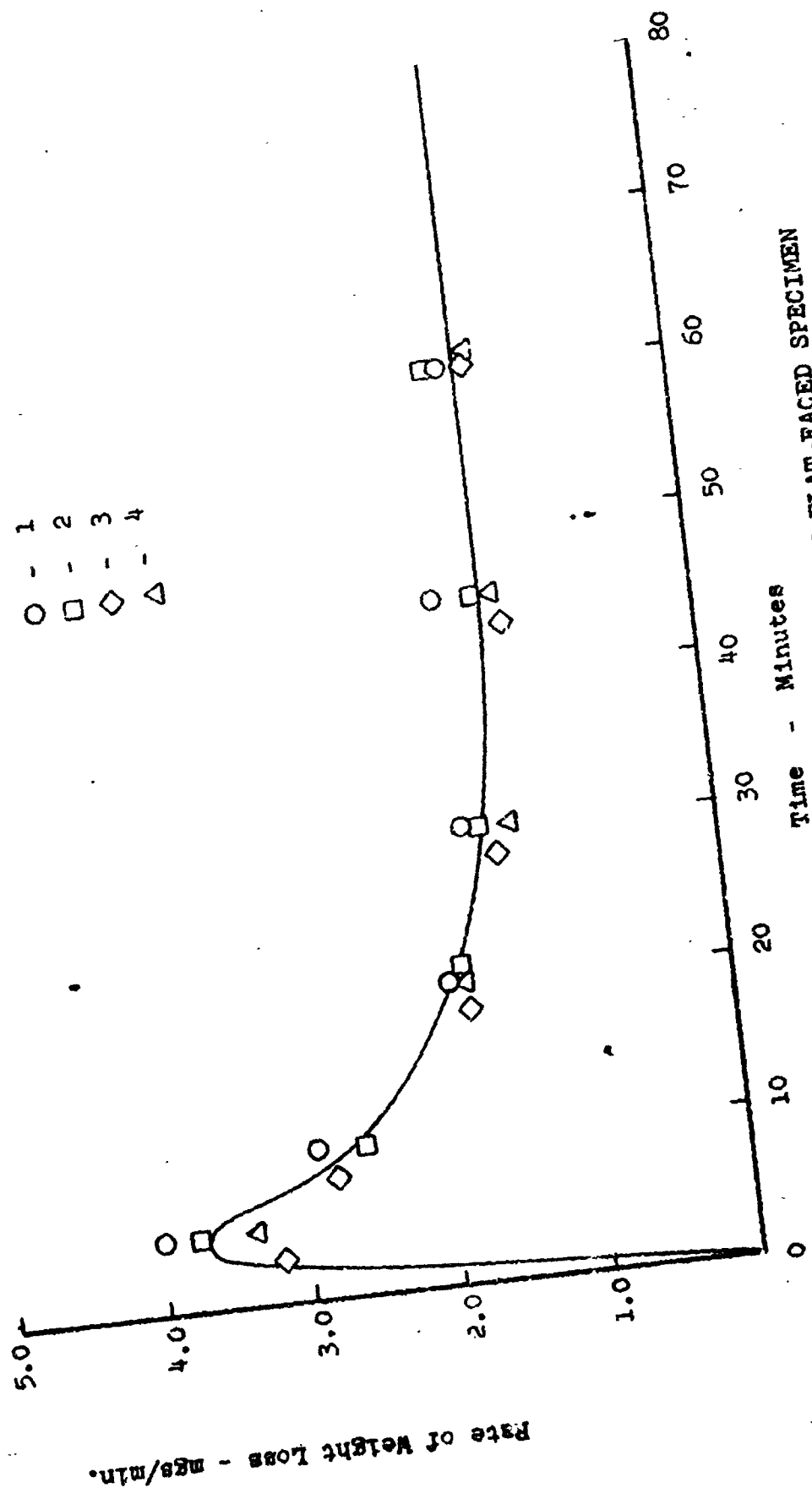


FIGURE 3. SHOWING REPRODUCIBILITY WITH FLAT-FACED SPECIMEN

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Material: 1100-0 Aluminum  
 Liquid: Water @ 80°F.  
 Amplitude:  $0.77 \times 10^{-3}$  inch.  
 Frequency: 15 kc/s

Specimen No.  
 ○ - 1  
 □ - 2  
 △ - 3

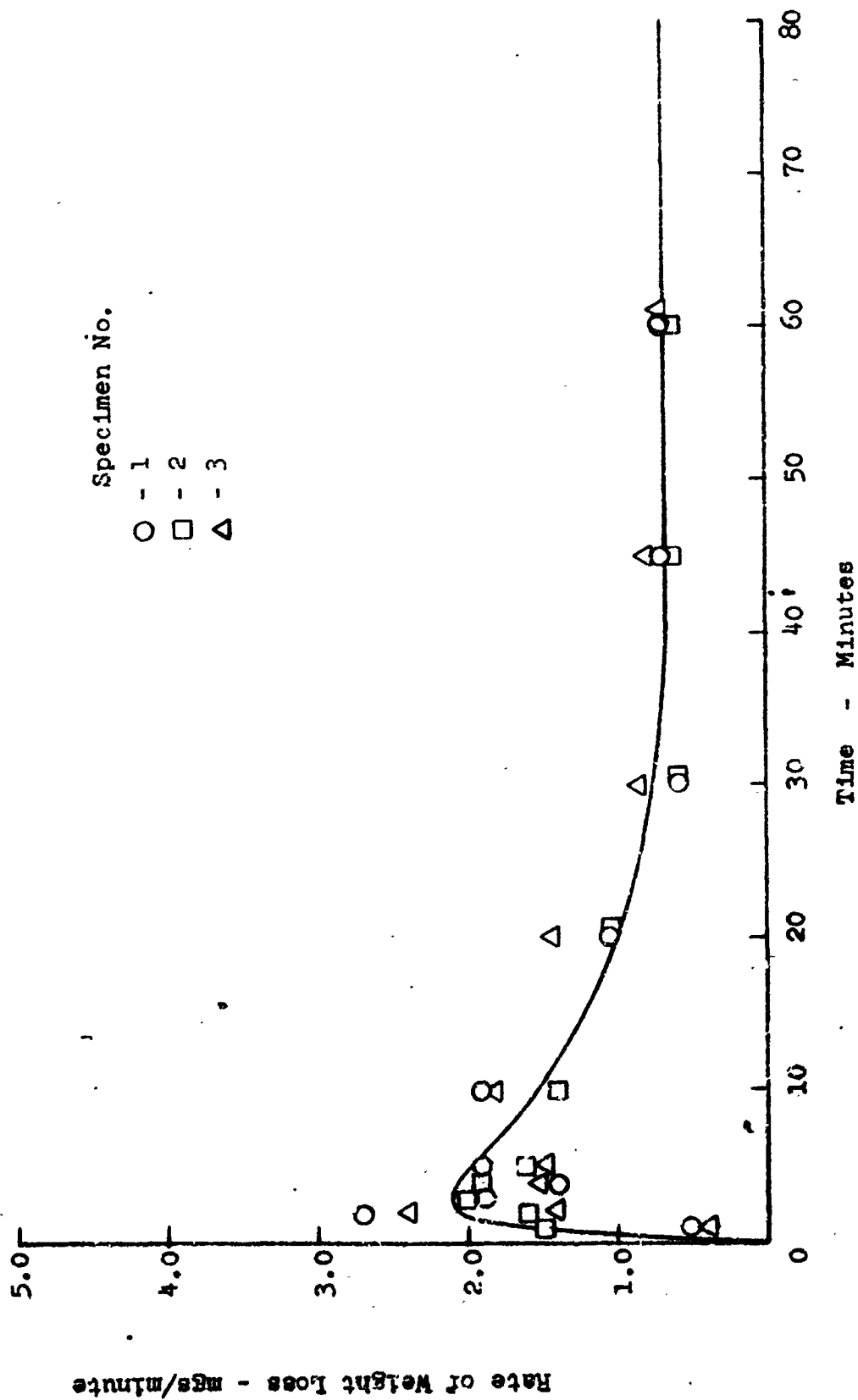


FIGURE 4. SHOWING REPRODUCIBILITY WITH PLESSET'S RIMMED SPECIMEN

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- - Flat Faced Specimen
- - Plesset's Rimmed Specimen

Frequency: 15 kc/s  
 Material: 1100-0-Aluminum  
 Liquid: Water @ 80°F.

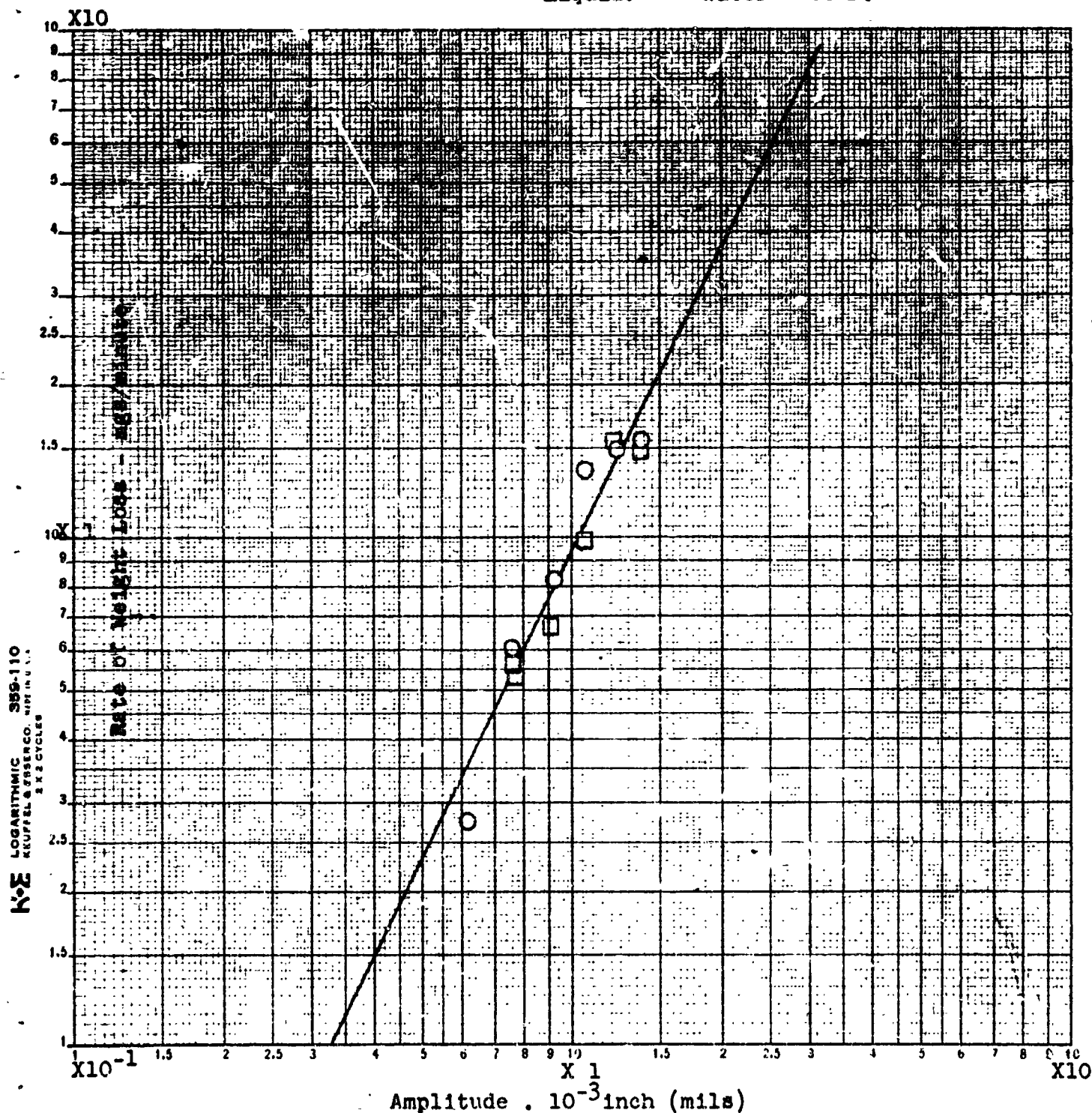


FIGURE 5. RATE OF WEIGHT LOSS vs AMPLITUDE FOR BOTH TYPE OF SPECIMENS

Amplitude:  $0.77 \times 10^{-3}$  inch.  
 Frequency: 15 kc/s  
 Material: 1100-0-Aluminum  
 Liquid: Water @ 80°F.

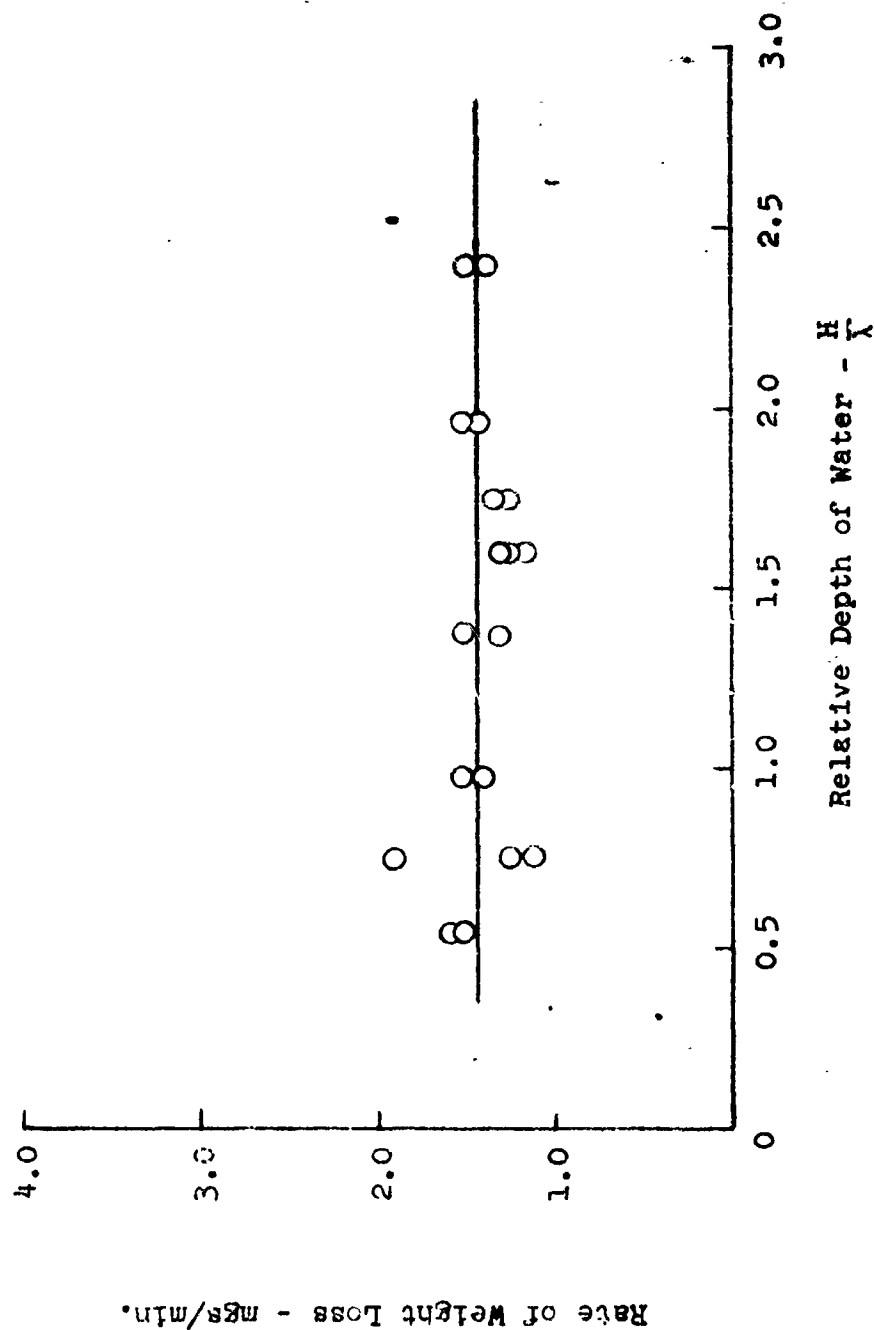


FIGURE 6. EFFECT OF DEPTH OF LIQUID IN THE BEAKER

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Amplitude:  $0.77 \times 10^{-3}$  inch.  
 Frequency: 15 kc/s  
 Material: 1100-0 Aluminum  
 Liquid: Water @ 80°F.

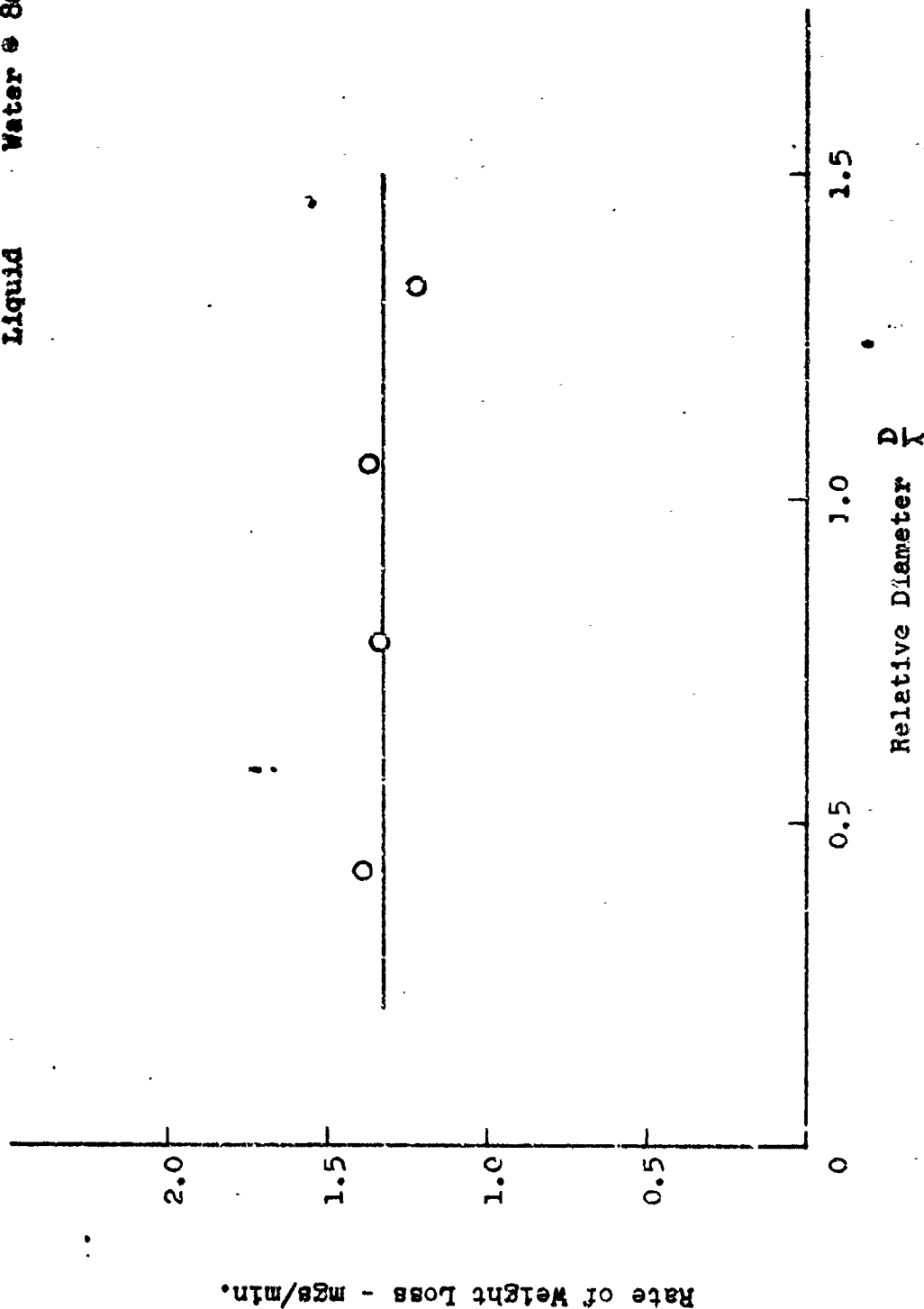


FIGURE 7. EFFECT OF BEAKER DIAMETER

Amplitude:  $0.77 \times 10^{-3}$  inch  
 Frequency: 15 kc/s  
 Material: 1100-0-Aluminum  
 Liquid: Water @ 80°F.

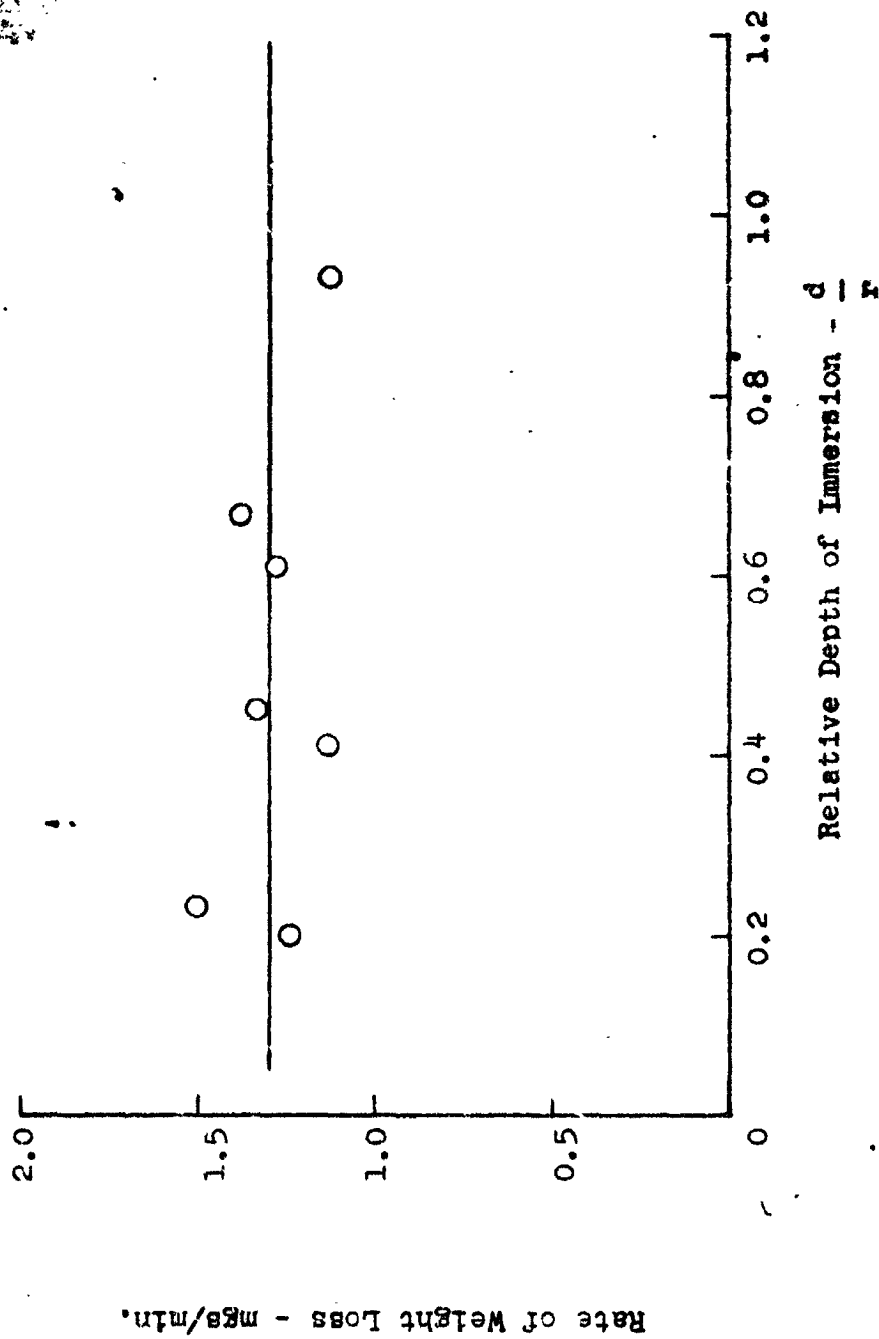


FIGURE 8. EFFECT OF DEPTH OF IMMERSION OF WATER